



Concept of Operations Visualization in Support of Ares I Production

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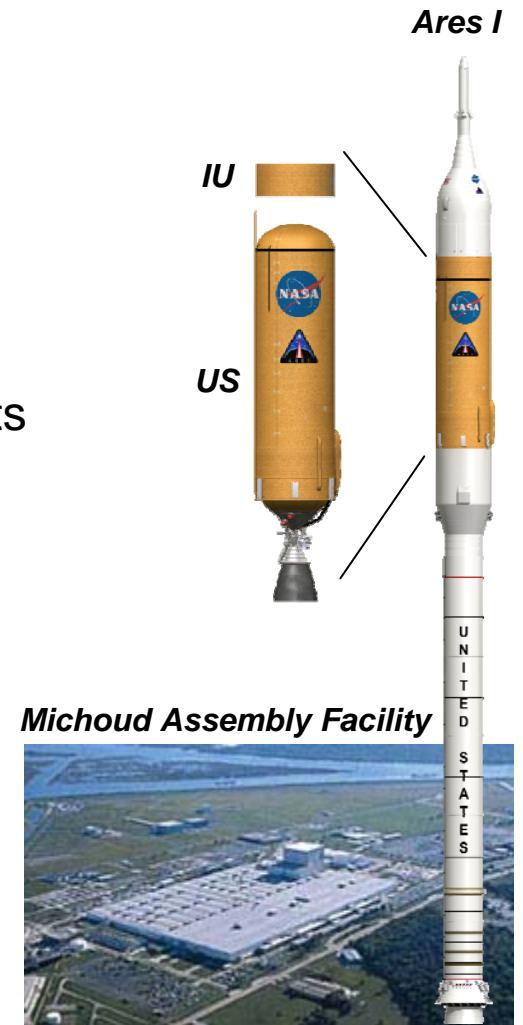


Introduction

Boeing Production of Ares I Upper Stage and Instrument Unit

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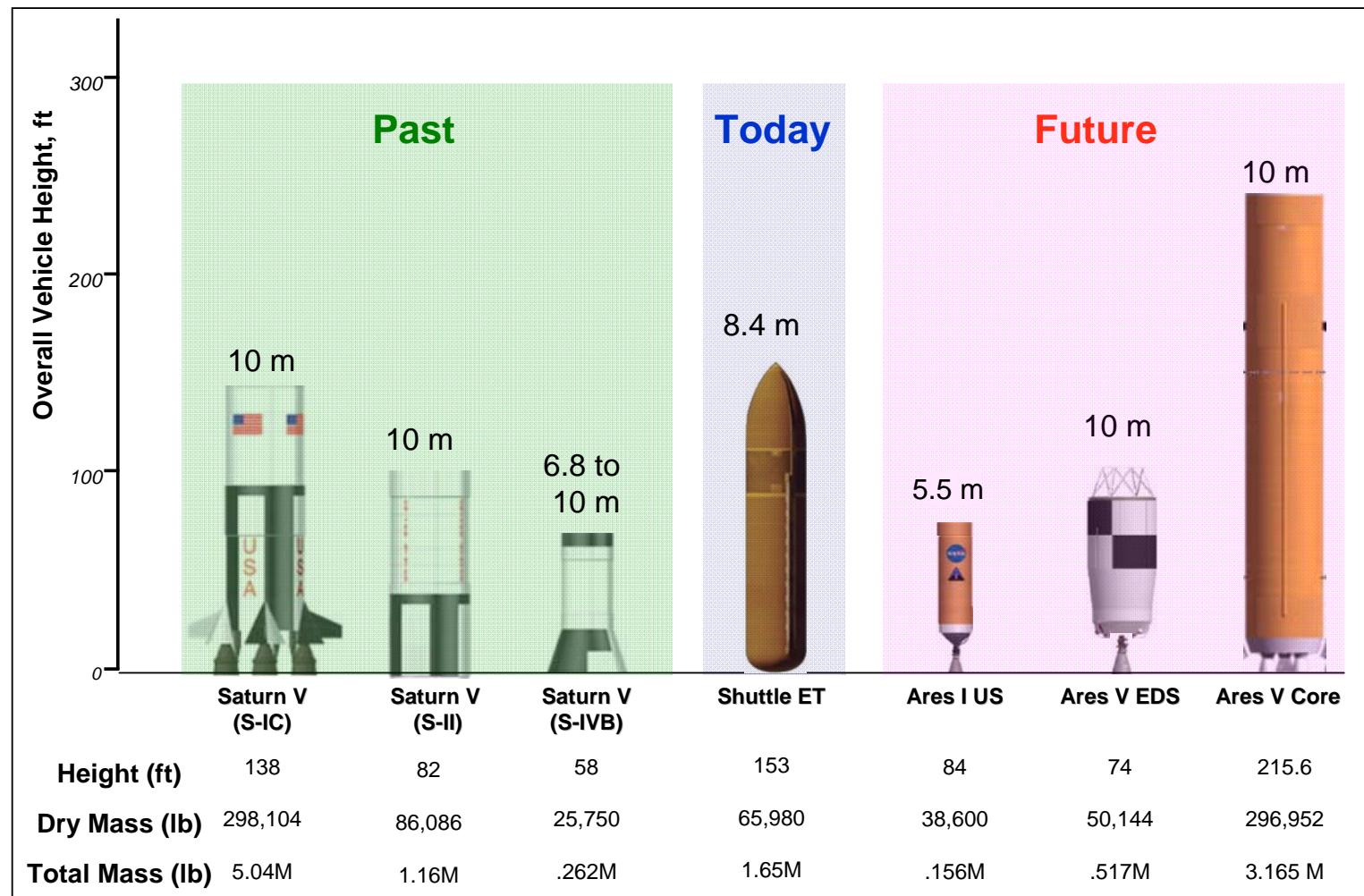
- **Boeing selected in 2007 to manufacture Ares I Upper Stage (US) and Instrument Unit (IU) to NASA's design**
 - Architecturally similar to Apollo/Saturn 3rd Stage
 - Requires use of latest manufacturing and integration processes to meet NASA budget and schedule targets
- **NASA Marshall Space Flight Center (MSFC) and Boeing are working together to develop cost effective and lean US/IU production**
 - Production at MSFC's Michoud Assembly Facility (MAF) outside of New Orleans, Louisiana
 - One of the largest manufacturing plants in the world (174,000 m²)



Comparison of MAF Manufactured Stages

Saturn/Shuttle/Ares

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Need for CONOP Visualization/Simulation

Reduces Life Cycle Cost during early design

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- **NASA challenge: convert MAF into 3rd generation liquid oxygen/hydrogen rocket stage factory**
 - Minimize disruption to ongoing Shuttle External Tank operations
 - Produce 2 to 6 Ares I Upper Stages/year for ISS missions
 - Produce up to 2 Ares V vehicles/year for lunar missions
- **Production experience: 80% of life cycle cost established during first 20% of design process**
 - NASA tasked Boeing with producibility analysis for Ares Upper Stage
 - Boeing aircraft (e.g. 737, F-18, Chinook) and spacecraft (Shuttle, ISS) production demonstrate value of virtual manufacturing and CONOP visualization during early design
- **Production and operation visualizations can reduce tooling, factory capacity, safety, and build process risks while spreading program support across government, academia, media and public constituencies**

NASA/Boeing Production Visualization

DELMIA (Digital Enterprise Lean Manufacturing Interactive Application)

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- **Promotes timely, concurrent and collaborative producibility analysis (Boeing) supporting Upper Stage Design Cycles (NASA)**
 - Assembly Simulation (30% - 45% typical savings)
 - Validates operation sequences & tooling concepts
 - Enables optimization of assembly processes
 - Reduces downstream production planning
 - Human Factors/Ergonomics (45% - 55% typical savings)
 - Identifies hazardous operations (hardware/ personnel)
 - Ensures accessibility during assembly/test/ operation/maintenance
 - Factory Definition and Analysis (50% - 75% typical savings)
 - Validates floor space & factory operations
 - Validates operation sequences & large scale tooling concepts
 - Highlights capital investment requirements
 - Identifies assembly anomalies

Ares I IU Production CONOP/Simulation

Validated avionics assembly and handling

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■ Movie Here

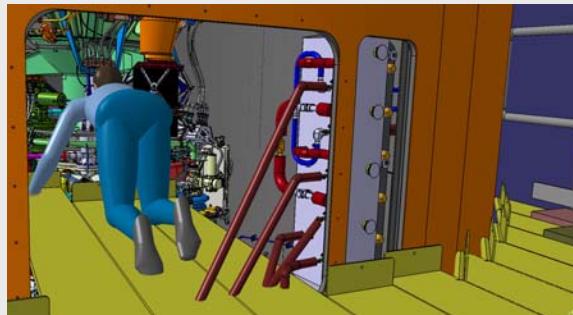
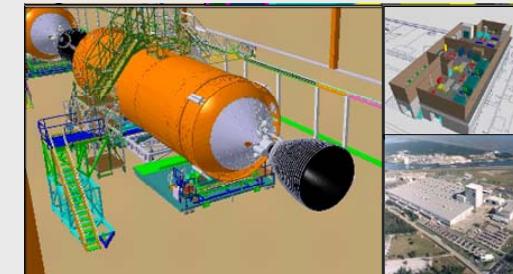
Benefits of DELMIA CONOPs Visualization

Production and Launch Operations

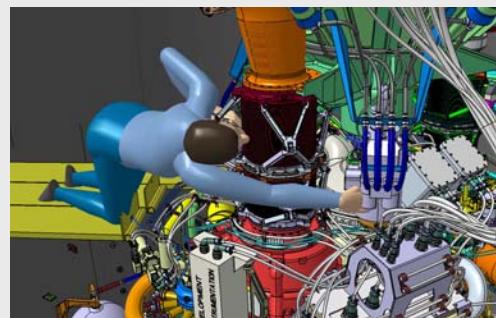
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- **NASA and Boeing reduced overall Upper Stage production flow time at MAF by over 100 man-days to 312.5 man-days**
- **Identified technician access issues during Launch-48 hours to remove the Ares I Thrust Vector Control (TVC) Actuator Locks during Preliminary Design Review**

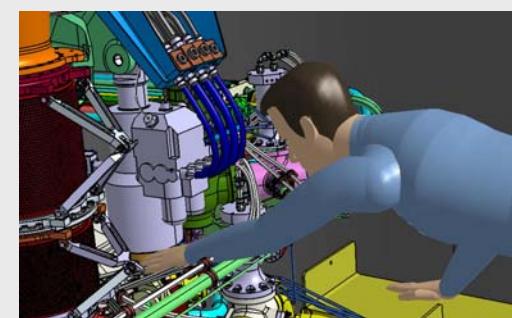
DELMIA virtual manufacturing simulation validated a 25% reduction in Upper Stage assembly man-days



Technician access obstructed to J-2X engine in Ares I Interstage



Technician easily accesses J-2X TVC "left" Actuator Lock.



Technician strains to access J-2X TVC "right" Actuator Lock.

NASA/Boeing Flight Operations Visualization

ICON (Interactive Concept of Operations)

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- **Boeing and NASA developed flight ops visualization analog to production visualization**
 - Provides context for Ares element (Ares I and V) production at MAF over many years
 - Illustrates range of Constellation element types, scale of time and complexity of interfaces required of Ares vehicle family
 - Presents benefits of Constellation investment by visualizing architecture and describing the benefits to the implementers (industry), owners (public) and financiers (government)
- **ICON provides interactive access to Ares using real mission parameters**
 - 2-D data (such as trajectory, or ephemeris data, operations schemas, slides, spreadsheets, movies, documents, or web-based data)
 - 3-D data (such as CAD models, contour maps, terrain maps, etc.)
 - Specific different user views (selectable cameras)

Ares ICON Simulation

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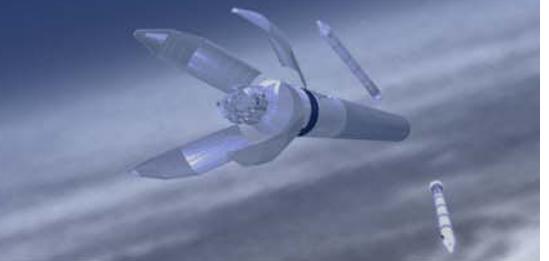
▪ **ICON Here**

Benefits of ICON Visualization

Ares ISS, Lunar and Mars flight operations

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- Ability for user to configure mission encourages ownership and identifies areas for improvement
- Mission options (e.g., Orion abort) or spacecraft detail (e.g., Interstage components) added as needed
 - Allows quick customization for unique audience and tailoring of messages
- Effective, low cost advocacy, outreach and education tool
 - Used to help science community visualize potential Ares interplanetary applications



Mission Configuration Screen



Ares I Upper Stage De-orbit Segment



Conclusions

CONOP visualizations will be critical to sustaining Ares/Constellation

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- NASA and Boeing have used a variety of visualization tools to enhance design producibility and more effectively understand Ares operations
- DELMIA and ICON visualization provides timely insight into potential system problems and allow cost effective evaluation of alternate approaches
- The collaborative nature of DELMIA and ICON visualization and simulation tools can significantly reduce design cycle time and encourage a diversity of involvement across Ares/Constellation elements
- These tools identify changes earlier in the life cycle where the cost of change is less and promotes greater interaction and ownership by a larger pool of Constellation constituents (government, industry, academia, media and public)